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AIR WEATHER SERVICE MANUAL

TERMINAL FORECASTING

Part I

Extrapolation Techniques for Short-Period Terminal Forecasting

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HEADQUARTERS
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FOREWORD

1. Purpose. To provide AWS Forecasters with techniques particularly suited to short-period terminal forecasts of one to three hours.

2. Scope. This is Part I of a planned AWSM 105-51 series on terminal forecasting. This Manual is provided with an expansible binding so that additional parts, chapters, or appendices can be included later as issued. Part I is limited to very short-period terminal forecasting methods based largely on extrapolation. Various techniques for forecasting visual elements are suggested as well as a systematic means of charting the surface and upper-level conditions in the local region of interest. Although experience with some of the suggested procedures is limited, they are believed to have merit, and should be further field-tested where operational conditions permit. This headquarters should be advised of results of field experience with these and/or other similar techniques or aids to terminal forecasting, which will be considered for future revisions and parts of this Manual.

3. Additional Copies. This Manual is stocked at Headquarters MATS, Command Adjutant, Publishing Division. Additional copies may be requisitioned from Headquarters Air Weather Service, ATTN: AWSAD, in accordance with AWSR 5-3, as amended.

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Chapter I

INTRODUCTION

The problem of accurate short-period terminal forecasting has long been with us; however it did not become critical until the wide-spread use of jet aircraft. Flight plans for conventional aircraft are actually computed on a "busted" terminal forecast basis, i.e., alternate plus a safety-margin-of-fuel consideration. This is quite critical with jets; owing to their high rate of fuel consumption, there is less time to make decisions and change plans. Even where conventional aircraft are concerned, it is frequently overlooked that while the aircraft may land "somewhere" safely, the operational impact on the mission of landing at an alternate may be tremendous.

The purpose of this Manual is to suggest the type of methods which are peculiarly suited to preparing forecasts for periods of one to three hours. Some of the methods outlined deal with specific parameters; others are more general in nature. However, each technique may be used either independently or in conjunction with other forecast considerations.

All of the techniques presented are based on a single forecasting principle — extrapolation. Extrapolation is the most powerful short-period forecasting tool currently available to the meteorologist. Although the potential value of other more "physical" forecasting principles is not questioned, at this time the easiest and most rapid improvement in short-period terminal forecasting may be realized through vigorous exploitation of extrapolation techniques. This Manual describes some of these techniques.

<u>Extrapolation</u> is the estimating of the future value of some variable from observations of its present and past values. In the simple techniques discussed here the extrapolation is taken linearly, with only very crude (if any) consideration of accelerations. The quality and frequency of observations do not generally permit or justify use of more sophisticated techniques for treating accelerations, nor do short-period forecasts generally require them. Even the simplest methods, however, are quite sensitive to the quality and time-spacing of the

observations as well as the quality of any analysis of these observations.

In the case of short-period forecasting the quality of the observation is especially significant because of its close proximity, in time, to the forecast itself. The hourly sequences obviously cannot provide a complete nor even adequate picture of the weather under all conditions. When special conditions prevail, the REMARKS section provides opportunity for amplifying the observation. This may be of great importance in bad flying weather. The observers and forecasters should utilize the REMARKS section as much as possible to this end.

Imminent introduction of the rotating-beam ceilometer and the transmissometer emphasizes a problem which is particularly important in short-period terminal forecasting, i.e., the very short-period variation in ceiling and visibility. During occurrences of low ceilings and visibilities these parameters often vary by a factor of ½ or so around some mean value over periods of as little as one to three minutes. For example, rotating-beam-ceilometer records show cloud bases varying from a reported 300 feet to 200 feet and then up to 400 feet in less than one minute. Transmissometer records indicate similar occurrences relative to visibility. Even more extreme variations are not uncommon. Unfortunately, little specific guidance can be given on how to handle this variability problem from a forecasting point of view. Nevertheless, it is important that both forecasters and their customers be aware of it. Meanwhile, an experimental program to explore possible methods for integrating this type of ceilometer and transmissometer information into current forecasting techniques is under way.

As further suggestions on short-period terminal forecasting become available they will be issued as additional parts to this Manual or in other manuals. Each detachment is encouraged to place in the binder for this Manual, other available material germane to short-period forecasting.

Chapter II

NEPHANALYSIS

2.1. <u>What is Nephanalysis?</u>

Nephanalysis may be defined as any form of analysis of the field of cloud cover and/or type. It is not yet a well-developed conventionalized system of procedure. In particular, very little practical experimentation has been done with the synoptic analysis of either cloudiness or cloud-type by means of special charts. The potentialities of specialized nephanalysis may seem to be obvious, but in practice difficulties are encountered, viz.:

a. The cloud observations received in synoptic codes permit only a highly generalized and incomplete description of the actual structure and appearance of the cloud systems.

b. The observation stations are usually too far apart to permit a representative picture of the distribution of many features which have a high degree of spatial and time variability.

c. So many parameters are observed that they cannot all be readily analyzed on one chart.

In view of these limitations, it is recommended that all forecasters considering the use of nephanalysis approach it with an open mind for experimentation. They should select for analysis only the particular parts of the cloud observations which are important to the intended application, and then adjust the chart scale, the degree of detail, and the mode of representation to the character of the data and to the purpose. The literature unfortunately offers practically no guidance on this.

There will be some reluctance to adding special cloud charts into the station routine. For many purposes, special neph-charts should not be necessary because sufficient nephanalysis can be performed on the regularly prepared surface synoptic charts, perhaps with the aid of an acetate overlay. At present, few forecasters make full use of the cloud reports plotted on their charts, and often many cloud reports are omitted from the plotting. Obviously, the first consideration in nephanalysis is to survey what cloud information is transmitted and to see that everything pertinent is plotted on the regular charts. For very short-period forecasting the charts at 6-, 12-, and 24-hr intervals are apt to be insufficiently frequent for use of the extrapolation techniques to be discussed below. Consideration, therefore, must be given to plotting neph-charts or surface charts (for a small area at least) of the intermediate 3-hourly synoptic reports and even of hourly sequences. A disadvantage of the separate neph-charts is that the correlation of the cloud analysis with the analysis of closely related phenomena (which usually also have to be forecast) is made more cumbersome. Integrated analysis and forecasting of ceiling, visibility, cloud cover, and precipitation is more economical and successful because these elements are physically dependent on the same synoptic processes. The fact that the forecasting of each element is discussed separately in this Manual is not meant to imply that such a rigid separation should or can be followed in practice.

2.2. Lee's Method of Middle-Level and High-Cloud Forecasting with Aid of Nephanalysis.

A report written by R. Lee [1], published by the Canadian Meteorological Service, contains a unique chapter on the use of nephanalysis from hourly observations in short-period forecasting of middle cloudiness for terminals in eastern Canada. Some ideas and examples from it are included in this Chapter. Lee used nephanalysis in several forms, including special neph-charts, to extrapolate movements and types of general cloud systems. Thus, his nephanalysis appears as an aid rather than as an independent method for producing the final forecast. (It is conceivable, of course, that nephanalysis could be devised to provide forecasts independently of other aids, although this is believed to be inherently undesirable.)

2.3. Plotting and Analysis.

Nephanalysis of the types used by Lee may be done as follows:

2.3.1. Determining the Coverage of the Nephanalysis. Let us assume that the area and shape of middle-cloud sheet changes relatively little with time, i.e., it is essentially translated. Then we can say that the local changes at our terminal in the next few hours will be caused by the existing cloud formations in the direction from which they are moving. The cloud analysis over a band about 600 miles wide centered on our terminal and oriented upstream with the current 500-mb flow is sufficient to include all the middle and upper clouds likely to affect our terminal in the forecast period. The length of the upstream area analyzed depends on the speed of the upper winds, or on the motion of the surface pressure system with which the neph-system is associated. For example, if the clouds were moving at a speed of 60 knots, an analysis extending 360 nautical miles upstream would be adequate to forecast middle- and high-cloud changes for a 6-hour period.

2.3.2. Plotting. The extent and method of plotting a neph-chart depends on the individual synoptic situation and may be accomplished in a number of ways. It is essential in all cases, however, that the cloud reports to be used as predictors are plotted at sufficient locations to permit a quick and usable analysis to be made.

Cloud information is transmitted in various forms in the several codes. Since many forecasters are not familiar with the scope of this information, a listing of the pertinent groups, symbols, and specifications in each code as of December 1956 is given in Appendix A. If separate neph-charts are to be constructed, a special plotting model must be devised for the particular code reports desired. In general, it is recommended that the usual symbols or abbreviations for cloud type be used. However, in plotting from U.S. Airways Reports the letters "B," "S," and "T" are recommended for "broken," "scattered," and "overcast" instead of the teletype symbols in order to avoid confusion with the cloud-cover symbols in the station circle. Due to the different specifications or concepts used in the codes, difficulties in plotting and analysis may result from entering on one map reports transmitted in different codes. The confusion can be minimized by plotting reports from different codes each in a different color. (See Appendix A for applicable code forms.)

2.3.3. Analyzing for Neph-Areas: Neph-Curves and Isochrones. The neph-system, or entire cloud pattern over a large area (cyclone, anticyclone, etc.), can be analyzed into subordinate units, called neph-areas, which are outlined on a neph-chart (or on a surface synoptic weather map) by boundaries called neph-curves. The neph-areas may be chosen as: 1) clear sky; 2) scattered C_L, C_M, or C_H; 3) broken C_L, C_M, or C_H. The choice of neph-curves to be entered on a particular chart depends on the type of clouds in which the forecaster is interested. The attempt to analyze all possible neph-curves on one chart results in too complex a picture (e.g., see [2]). In sub-section 2.4.3 lower-cloud and also middle-cloud neph-curves are illustrated.

An extension of the neph-area analysis is suggested to facilitate cloud forecasting by extrapolation; isochrones of past hourly positions of certain neph-curves are added to the map. For example, the times (to nearest hour or half-hour) at which middle cloud first appeared for upstream stations could be plotted on a given neph-chart (or on the surface weather map) and isochrones drawn.

The drawing of neph-curves and isochrones is not without difficulties due to the apparent complexity of the patterns or to parse data. Usually, a degree of smoothing is in order — only experience can tell how much. Particularly with lower-cloud systems, the spottiness of the distributions may require a rather arbitrary nephanalysis unless suitable models can be developed. Limitations of the data must also be kept in mind. Often on moonless nights, the observers can only guess at the cloud types and amounts. Lower clouds generally show a marked diurnal variation. Also, terrain influences can be more prominent than those of the general synoptic processes.

2.3.4. Associating the Nephanalysis with Other Analyzed Charts and Soundings. It is obviously of great importance in nephanalysis to obtain an understanding of the relationship of the neph-systems, areas, and curves to synoptic features such as weather distribution, flow patterns, fronts, troughs, ridges, squall-lines, etc. When the nephanalysis is done on synoptic surface-weather maps, this correlation is greatly facilitated. Otherwise, it is suggested that surface 3-hourly frontal positions, 700- or 500-mb trough lines, instability-index areas, Z-bar lines, dew-point spread lines (aloft), etc., be traced onto the special neph-charts whenever it seems pertinent.

2.4. Forecasting from Nephanalysis.

2.4.1. Extrapolating Neph-Curves. A simple, quick, and generally valid method of short-period cloud forecasting is by extrapolation of the neph-areas and curves. It may be assumed that accelerations are relatively small and negligible over 3-hour periods. Experience indicates that this is acceptable — even in many developing situations. However, where other synoptic considerations clearly reveal likely developments, the extrapolation of neph-areas can be modified accordingly. This modification usually can be done by "eye." For periods over three hours, use of a graphical method such as Defant's [3] or Wasko's [4] on the neph-curve movements possibly would be of value. The extrapolation may be performed on entire neph-areas as units, on individual points in the neph-curves, or on points in the isochrones of the neph-curves. It is also advisable to carefully examine the nephanalysis and extrapolations in conjunction with the corresponding upper-level contour charts (current, prognostic, and Z-bar) to see what cloud motion might be expected from the wind-field. (Cloud systems generally move slower than the winds* [5].) When the neph-curves cannot be determined accurately due to a sparse station network, isochrones may be very inaccurate and extrapolations from them cannot be made with confidence. Under such conditions the previous cloud-changes with time at given individual upstream stations may be used to indicate probable future changes at particular downstream stations. Here, it is assumed that stations affected by the same neph-area(s) of a neph-system will have similar weather (cloud) sequences. Obviously, in rapidly developing situations the assumption is of limited validity unless the forecaster can track the advective and development trends separately. For example, suppose that middle cloud made its first appearance at the upstream station at 1230Z, followed by a change to an overcast deck of altostratus by 1530Z. Knowing the past movement of the clouds, or wind field at the altostratus levels*, and the distance between the stations, a first approximation to the arrival of middle cloud would be 1230Z plus the time required for the cloud to move by translation alone. Due to the neglect of other synoptic developments, the error in this forecast may be large. However, once the middle cloud first appears, say at 1730Z, as scattered altocumulus, the timing of overcast conditions can be estimated by the knowledge of previous events at the upstream station. That is, three hours hence at 2030Z, it may be expected that the scattered middle cloud will increase and become an overcast deck of altostratus. In a similar manner, one can use the time intervals between the appearance of overcast altostratus and the beginning of continuous precipitation as a forecast indicator, or the interval between the beginning of precipitation and the appearance of a lower cloud form.

Some variation in procedure is in order not only according to the element or cloud feature to be forecast but also according to the character of a given neph-system. Systems moving at 30 to 40 knots were found by Lee to require a large upstream nephanalysis area using 3-hour intervals only, limiting the intermediate hourly nephanalysis to immediate upstream areas. The extrapolation is done on the nephanalysis for the limited area, using the features identified on the larger-area

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* If 500-mb Z-bar chart is available assume clouds move with 80% of the Z-bar flow; otherwise see Appendix B for suggested simple alternative procedure.

charts.

The extrapolation of lower clouds (like their analysis) will be found much more difficult than for middle clouds. The relation of the lower clouds to the synoptic features is complicated by influences of terrain (heating, cooling, orographic effects, diurnal variation, friction, etc.). As a result, the cloud areas are apt to show an irregular translation, so that extrapolation may not be very successful even if the difficulties in analysis were overcome. It is probable that extensive local experience and the study of radar echoes (see Chapter VII) are the best means of making short-term nephanalysis and forecasting of lower clouds a practical art.

As to accuracy, the experience in Canada suggests an error of the order of half an hour for two hours in advance. This might be improved with increased experience. Relatively higher accuracy may be expected for locations directly in the path of a low than for those which lie near the border of a neph-system.

2.4.2. Forecasting Weather with Aid of Neph-Progs. Having made an extrapolation of neph areas and curves, isochrones, etc., a further interpretation in terms of associated weather (precipitation, temperature, etc.) is often feasible. This, however, usually demands an equal consideration of the air-mass structure, stability, moisture distribution, pressure pattern, probable vertical motion field, etc. Thus, the nephanalysis becomes a special aid to the usual methods for general weather forecasting and serves to sharpen the outlook for periods of less than 10 hours.

2.4.3. Example of Nephanalysis of Lower and Middle Clouds for Northeastern United States, 10 August 1954, 0300-1200Z. Figure 1 shows examples of nephanalyses using the proposed plotting model. Superimposed on the nephanalyses are the surface fronts traced from the 0630Z surface map.

An illustration of the technique of analyzing cloud-cover changes with isochrones is shown in Figure 2. The times when overcast middle cloud first appeared at each station were abstracted from hourly weather reports. The change in overcast middle cloud was then analyzed by drawing the isochrones. Other significant changes in cloud cover could

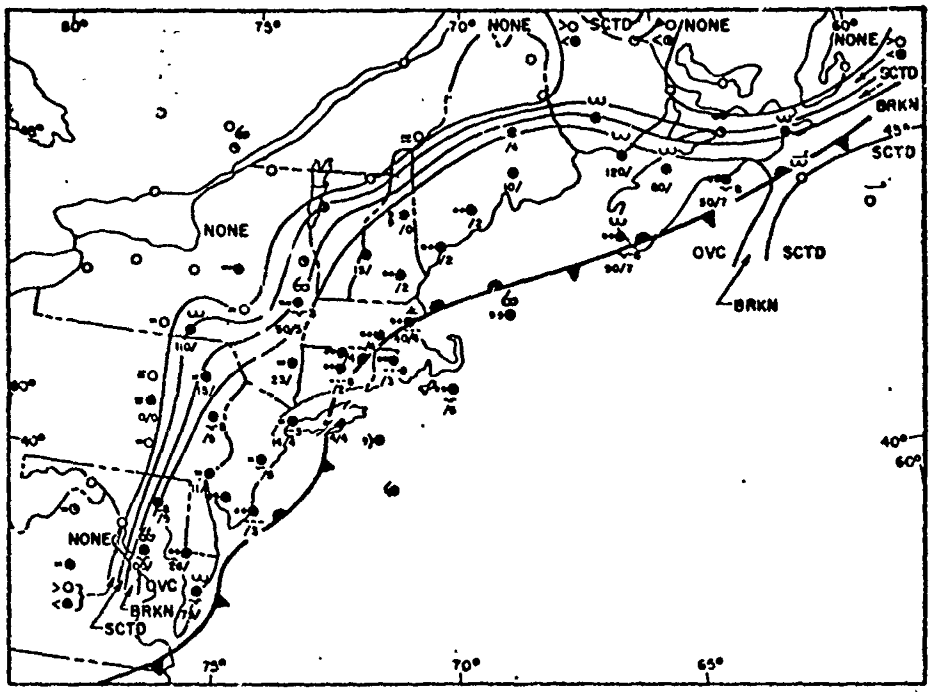


Figure 1a. Low-Cloud Nephanalysis, 0630Z, 10 August 1954.

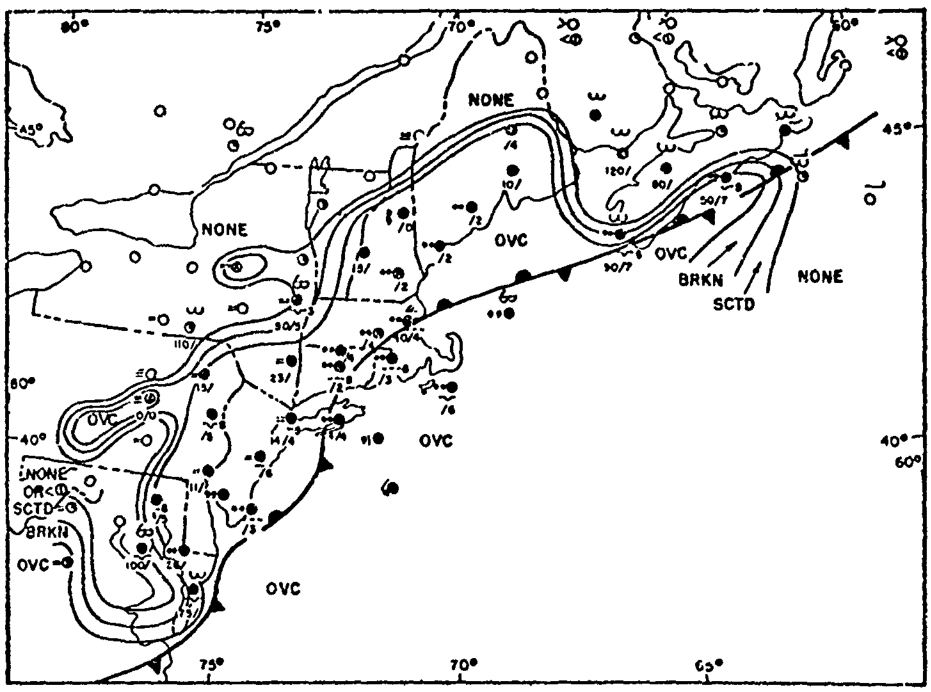


Figure 1b. Middle-Cloud Nephanalysis, 0630Z, 10 August 1954.

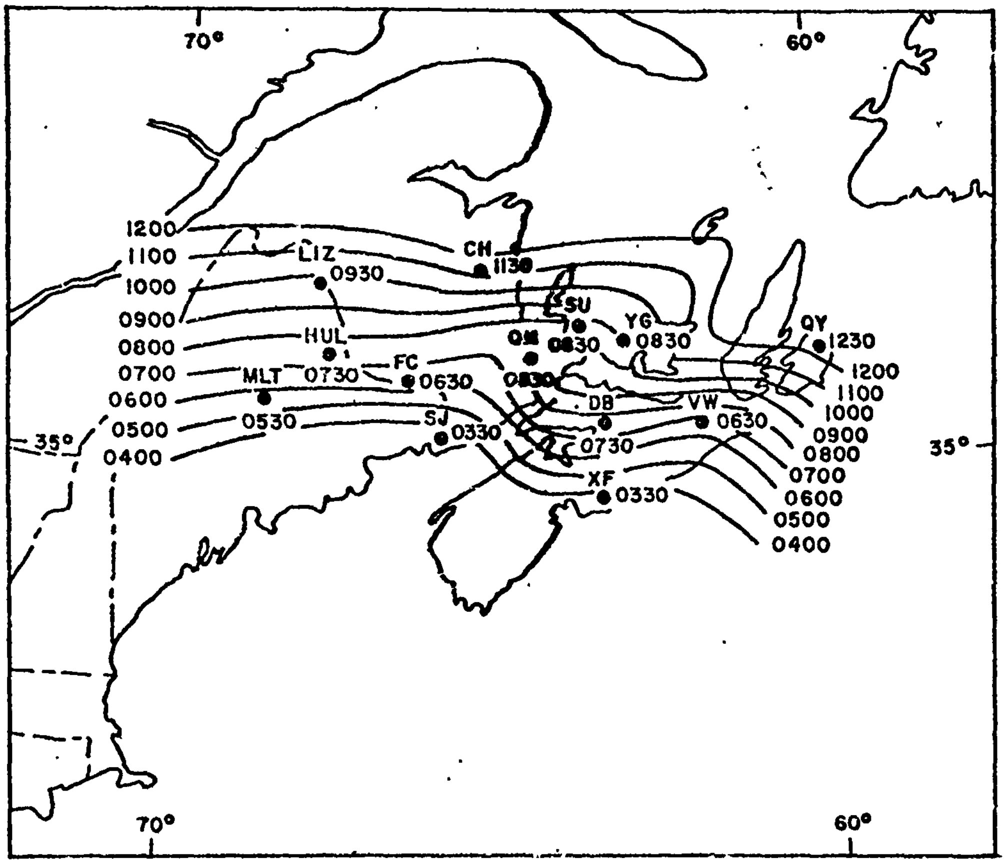


Figure 2. Time of Arrival of Overcast Middle Cloud, 0300Z – 1200Z, 10 August 1954.

be handled in a similar manner. From the regular spacing of the isochrones in Figure 2, it is apparent that the best method of forecasting the movement of the neph-system in this case would have been linear extrapolation.

2.5. Addendum.

In the AWS 2d Weather Wing Technical Bulletin for September 1956, Part II, pp. 45-56, is an interesting article by Maj. Ed. S. Maykut on "Nephanalysis and Short-Range Forecasting." His method is mainly an application to ADC problems at Orly, of the old (1923) Schereschewsky and Wherle method of nephanalysis (see Wea. Serv. Bull. Vol. 1, Nos. 1 and 2). This method is somewhat coarse-grained in scale and is tied to a model of cloud distribution around a typical west-European occluded cyclone, a model which has now been revised somewhat in the forthcoming new WMO International Cloud Atlas. This model probably cannot be used universally without modification.

Chapter III

FRONTAL PRECIPITATION

3.1. Introduction.

For the short-period terminal forecast the question about frontal precipitation is often not whether there will be any but when will it begin or end, e.g., in cases where it has already begun upstream or at the terminal. This problem is well suited to extrapolation methods. The prediction of new precipitation areas, such as those associated with new wave development, upper troughs, etc., of course, requires straightforward synoptic methods. However, for very short-period forecasting, the use of hourly nephanalysis (see Chapter II) often will serve to "pick up" new precipitation areas forming upstream, in sufficient time to alert a downstream target area. Also, the thickening and lowering of middle-cloud (altostratus) decks, generally indicates where an outbreak of precipitation may soon occur.

3.2. Forecasting the Movement of Precipitation Areas by Isochrones.

The areas of continuous, intermittent, and showery precipitation can be outlined on a special large scale 3-hourly or hourly synoptic chart, in a manner analogous to the customary shading of precipitation areas on ordinary synoptic surface weather maps. Different types of lines, shading, or symbols can distinguish the various types of precipitation (see Figure 3). Isochrones of several hourly past positions of the lines of particular interest can then be added to the chart, and extrapolations for several hours made from them if reasonable regularity in past motion is evident. A separate isochrone chart (or acetate overlay) may be easier to use. Lines for the beginning of continuous precipitation are illustrated in Figure 4. The isochrones for showery or intermittent precipitation usually give more uncertain and irregular patterns which result in less satisfactory forecasts.

Where large-scale sectional surface weather maps are regularly drawn, it may be sufficient and more convenient to make all the precipitation-area analyses and isochrones on these maps.

3.3. Forecasting Movement of Precipitation Areas by Means of a Distance vs. Time (x-t) Diagram.

The idea of plotting observations taken at different times on a

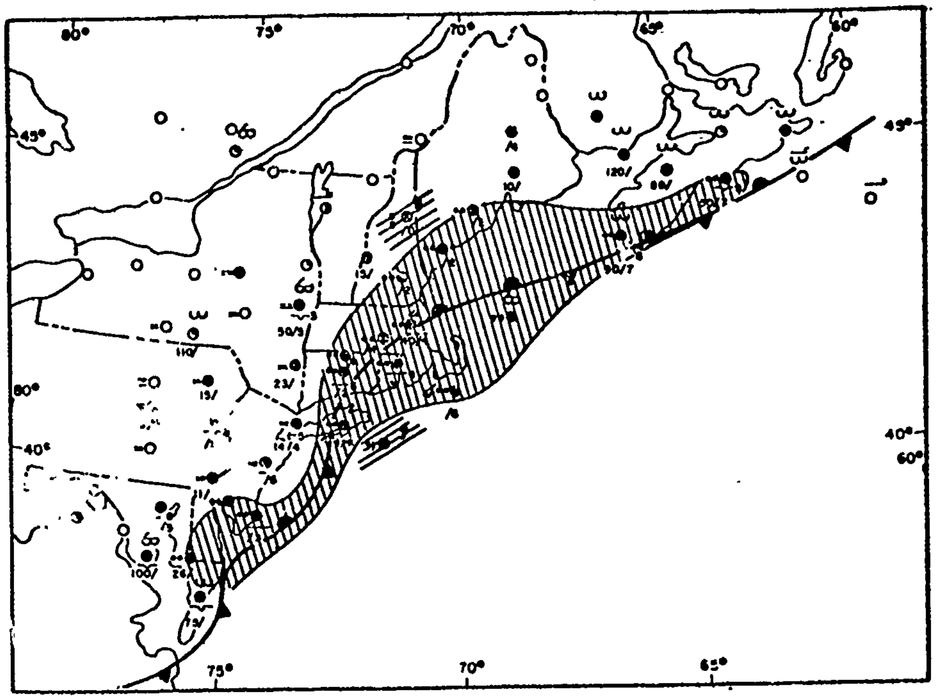


Figure 3. Precipitation Area Analysis, 0630Z, 10 August 1954. The area of continuous light rain which is hatched will be shaded in practice.

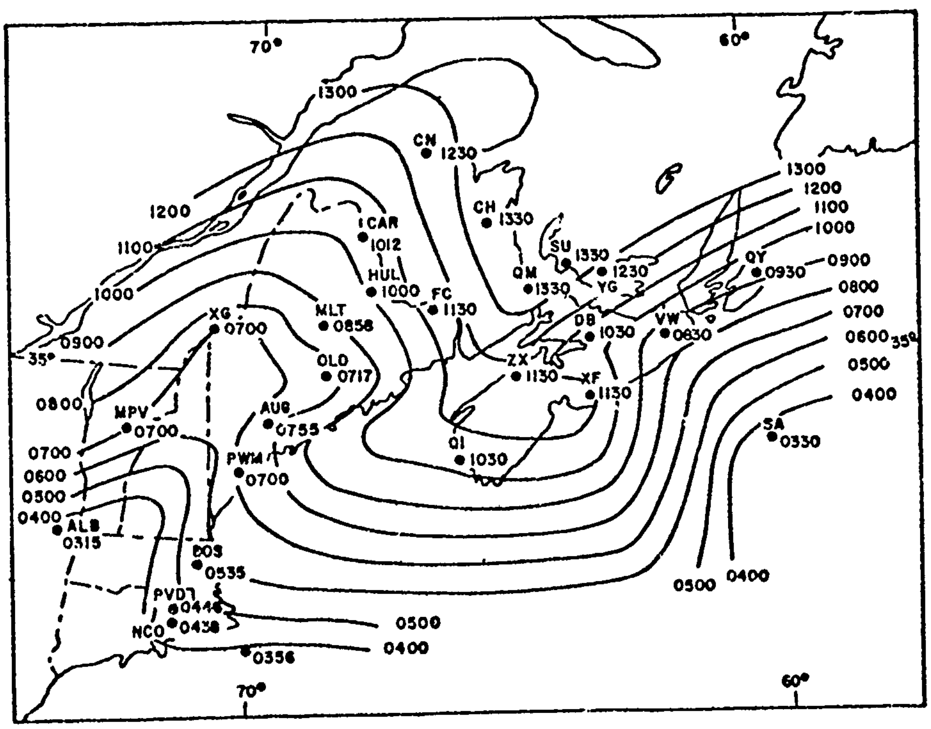


Figure 4. Isochrones of Beginning of Precipitation, 1 November 1954.

diagram which has horizontal or vertical distance in the atmosphere as one coordinate and time as the other is very old and has been used in various forms for diverse purposes by numbers of meteorologists. The time cross-sections much used in the tropics are a special case of this device, where successive soundings at only one station are plotted. The diagram of Stidd [6] has successive observations from various aircraft along a given route plotted so that time is represented on a distance scale. Lee [1] has used a diagram on which successive observations for stations along a given route are plotted at points scaled proportionate to the station separations. He calls it an x-t (i.e., distance-time) Diagram, which might be taken as a suitable general designation for the whole class of diagrams described above. On all of these diagrams an analysis can be carried out analogous to that on synoptic charts. Lee's version is of particular interest here because it is designed for regions with a normally dense synoptic network; whereas the time-cross section and Stidd Diagram are more suited for sparse-data regions. In the United States and southern Canada the forecaster can usually choose an axis line passing from his station through a series of stations in the direction from which the weather usually moves in, or from which it is expected during the particular situation. This line forms the distance, or x-axis of the diagram. The positions of the stations are marked off on it at their appropriate scale distances. Seldom, if ever, will many stations be found to fall exactly along a straight line; therefore in practice their positions are projected onto the x-axis. The time scale (increasing upward) is erected at right angles to the origin of the x-axis. Both coordinate axes have linear scales. Observations for any time and points reasonably near the x-axis may be plotted on this diagram, using the standard plotting models for airways or synoptic reports. A sufficiently open scale permits special reports to be fitted in easily, and hourly tendencies can be computed and added to the plotting. The resulting picture has somewhat the character of a plotted synoptic chart and can be analyzed accordingly. This type of diagram has many applications in short-period analysis and forecasting.

A situation involving an approaching cold front is illustrated in Figure 5. The x-axis was chosen at an approximately right angle to the cold front. A smooth curve joins the successive positions of the front as it passed successive stations. Such a curve can be extrapolated to

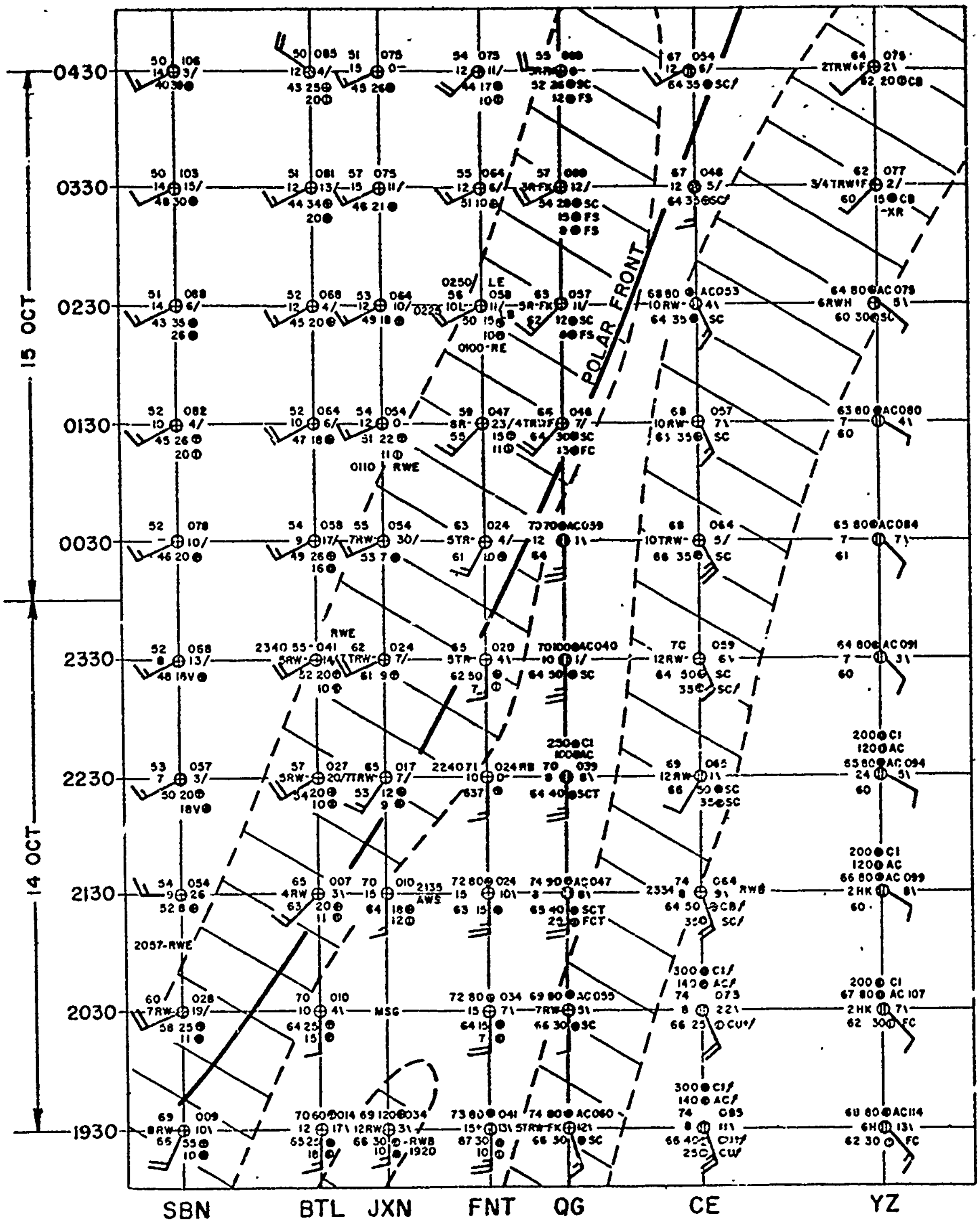


Figure 5. An Example of an x-t Diagram, 1930Z, 14 October — 0430Z, 15 October 1954. The positions of the front relative to the stations are indicated by the heavy continuous line. Showery areas are enclosed by broken lines and hatched.

future times and thus provide a forecast as to when it will pass your terminal (normally, the last station line to the right). The acceleration or deceleration in frontal speed is indicated by the curvature of the line, and this curvature can (if sufficiently regular, of course) be included in the extrapolation. This method of extrapolation is generally feasible and successful up to four hours. The results are most accurate when the phenomenon is moving regularly and at moderate speeds. When the complete synoptic models are plotted on the x-t Diagram, various factors affecting local movement and development of systems can be evaluated subjectively in making the extrapolation. For example, the interrelations of fronts, visibilities, winds, clouds, temperatures, pressures, and precipitation can be readily considered. Moreover, locally important details of the situation missed on the large-scale regular synoptic weather maps can often be spotted and followed on the x-t Diagram. On Figure 5, for example, two narrow bands of precipitation are outlined. They evidently could have been extrapolated for several hours with good accuracy.

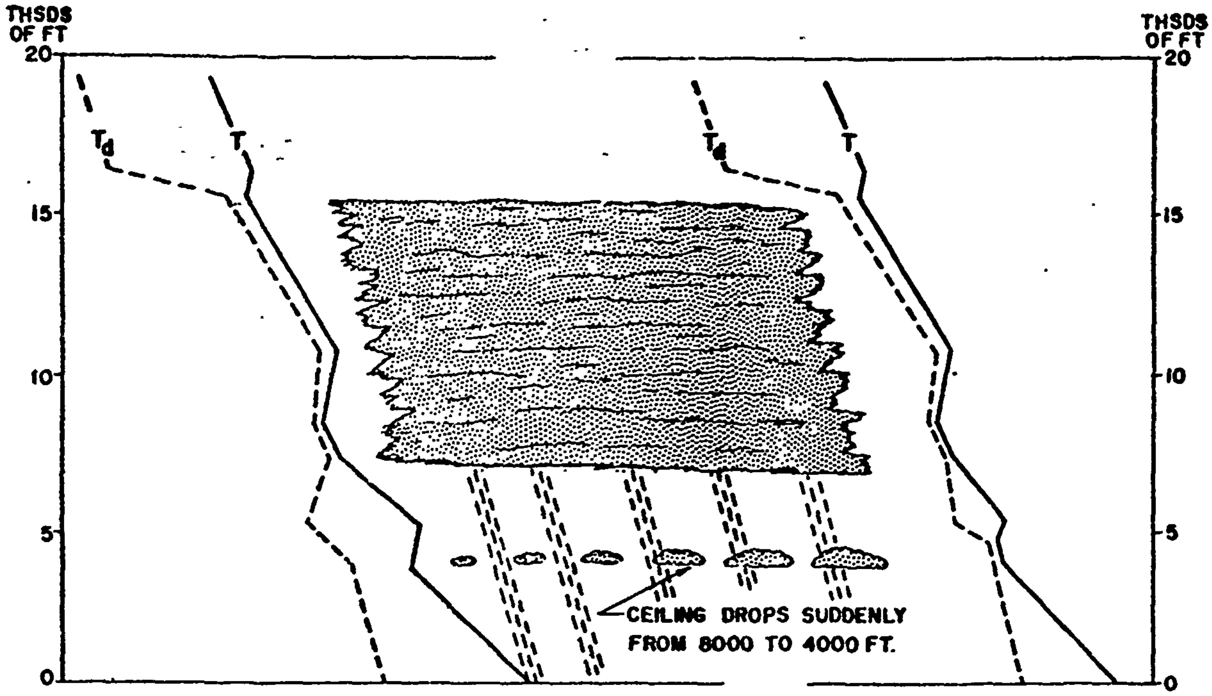
Chapter IV

LOWERING OF CEILING IN CONTINUOUS RAIN AREAS

4.1. Frontal Situations.

The lowering of ceilings associated with continuous rain or snow in warm-frontal and upper-trough situations is a familiar problem to the forecaster in many regions. The 6- to 24-hour forecast of such situations has been well discussed for the southeastern United States in AWS TR 105-82, December 1954. In very short-period forecasting the question as to whether or not it will rain and when the rain will begin is not so often the critical one. Rather, the problem is more likely to be (assuming the rain has started) how much will the ceiling lower in one hour, two hours, and three hours, or will the ceiling go below a certain minimum within the three hours. The visibility in these situations generally does not reach an operational minimum as soon as the ceiling, and fog usually becomes no worse than light. Dolezel [7] has shown why the evaporation of rain into calm, lower air — without sufficient convergence, or advection, or turbulence — does not lead to saturation and will cause no more than a haze or light fog. At some locations, as near the East Coast or where upslope trajectories are involved, advection effects may bring in moister air, stratus, or dense fog more or less independent of the rain-evaporation effect. (For forecasting in these cases other methods must normally be used — see AWS TR 105-82, AWSM 105-40, and AWSM 105-44.) Once stratus has formed, however, extrapolation of its displacement may be quite successful.

It is important to recognize the difference between the behavior of the actual cloud-base height and the variation of the "ceiling" height as it is arbitrarily defined in airway reports. In continuous rain the true base of a given cloud layer will descend gradually or steadily [7]; whereas the ceiling usually drops rapidly and in stepwise fashion — especially during the first few hours after the rain begins. The reason for this is that below the precipitating frontal-cloud layer there are usually shallow layers in which the humidity is relatively high and which soon become saturated by the rain. The cloud base itself has small random fluctuations in height superimposed on its general trend. Figure 6 illustrates this principle. Comparing radiosonde data and ceiling heights during rain at Portland, Maine,



Raob Sounding (Skew T, log p) Before Ceiling Dropped

Raob Sounding (Skew T, log p) After Ceiling Dropped

Figure 6. Illustration of Rapid Drop in Ceiling with Occurrence of Rain.

Goldman [8] found that the ceiling was much below the main frontal cloud base in more than half of the cases. He states the following empirical rules to aid in forecasting this discrepancy:

a. If the rain is of sufficient duration, a ceiling will occur below 2000 feet (usually it is 800 feet).

b. During continuous rain a ceiling generally does not occur at the height of temperature discontinuity (turbulence inversion) and/or maximum humidity until after the occurrence of a ceiling corresponding to the next higher level of temperature discontinuity and/or maximum humidity.

c. The ceiling remains practically constant until the next lower cloud layer appears and increases sufficiently for its base height to become the ceiling.

These rules must be applied to a radiosonde ascent close to the rain area in time and space. If no such radiosonde data are available, note the cloud-base heights reported in the rain area.

4.2. Timing of Lowering of Ceiling.

Forecasting the time when the ceiling of a given height will be reached during rain is a separate problem. Goldman [8], using physical reasoning similar to DoJ zel's [7], has developed a formula for estimating the moisture increase from rain evaporation. He thus devised an objective method for predicting the time of occurrence of a given ceiling at Portland, Maine. An empirical factor was necessary which may not be valid for points distant from there since it was determined only for Portland. Specifically, Goldman's method requires the following: 1) a nomograph giving time after start of rain at which air becomes saturated, as a function of wet-bulb depression at start of rain (from raob); 2) a table giving average values of temperature change (degree/hour) for various trajectory directions and cloud-base heights; and 3) solution of an equation relating the temperature change to the time for ceiling to reach a given height. He also developed a nomogram to estimate the wet-bulb depression aloft from surface data, for use when raobs are not available. The verifications for the objective method were quite good. Qualitative consideration of other factors should improve the results:

a. If a front or trough (with which low ceilings are associated) lies nearby, then the ceiling may lower more rapidly than forecast.

b. In cases of heavy rain or snow, the ceiling will lower more rapidly than forecast near the beginning of precipitation.

c. With strong turbulence near the ground the time of formation of very low clouds may be underestimated, while the time of formation of clouds near the top of the mixed layer may be overestimated.

d. Ceilings may not lower as rapidly as forecast in cases of intermittent or showery precipitation.

e. The time a ceiling of given height will occur may be underestimated if there is only slight advection of moist air at that level; if there is dry-air advection, the ceiling may rise (e.g., near the time rain ends).

If we lock upon evaporation as a slow and regular process which will give the basis for a simple extrapolation forecast, then the above factors will speed up or slow down the rate at which the ceiling lowers.

4.3. Extrapolation of Ceiling Trend by Means of an x-t Diagram.

The same sort of distance-time diagram illustrated in Chapter III can be used to extrapolate the trend of the ceiling height in rain. The hourly observations should be plotted for stations near a line parallel to the probable movement of the general rain area, originating at your terminal and directed toward the on-coming rain area. Ceiling-time curves for given ceiling heights (2000, 1500, 1000, 500, 300 feet, etc.) may be drawn and extrapolated. There may be systematic geographical differences in ceiling between stations due to local (topographic) influences which cause irregularities in the curves. Such differences sometimes can be anticipated from climatological studies, experience, or general inferences. In addition, there may be a diurnal (thermal) ceiling fluctuation which will become evident in the curves in slow-moving situations. Rapid and erratic up-and-down fluctuations also must be dealt with where the ceiling is uneven due to scud or "holes" of small diameter. In this case a smoothing of the curves may be necessary before the extrapolation can be made. This probably will cause the forecast to be proportionately less accurate.

In view of the discussion in Sections 4.1 and 4.2, it is not expected that mere extrapolation can be wholly satisfactory at a station when the ceiling lowers rapidly during the first hours of rain as new cloud layers form beneath the front. However, by following the ceiling trend at surrounding stations as well, a pattern of the abrupt ceiling changes may be noted. These changes at nearby stations where rain started earlier may give a clue to the likely sequence at your terminal.

Chapter V

THE TREND CHART AS AN EXTRAPOLATION AID

5.1. Purpose of the Trend Chart.

The trend chart can be a valuable forecasting tool when it is used as a chronological portrayal of a group of related factors. It has the added advantage of helping the forecaster become "current" when coming on duty. At a glance the relieving duty forecaster is able to get the picture of what has been occurring at his terminal. Also he is able to see the progressive effect of the synoptic situation on the weather at his terminal when the trend chart is used with the current map.

5.2. Trend-Chart Format.

The format of a trend chart should be a function of what is desired from it; consequently it may vary in form from station to station. It should, however, contain those elements which are predictive in nature as well as the quantitative values of parameters to be forecast — such as ceiling and visibility. With this in mind, a suggested format is outlined below.

5.3. Using the Trend Chart.

The trend chart is merely a method for portraying graphically what forecasters generally attempt to put to memory. Included in the usual technique repertory of most forecasters is a list of key predictor stations. The forecaster utilizes the hourly and special reports from these stations as aids in making short-period forecasts for his own terminal. Usually, the sequences from these predictor stations are scanned and committed to memory. Stepwise, the method would be as follows:

a. Determine the direction source of the weather, i.e., upstream.

b. Select a predictor station(s) upstream and watch for the onset of the critical factor, e.g., rain.

c. Note the effect of this factor on ceiling and visibility at predictor station(s).

d. Extrapolate the approach of the factor to determine its onset at your terminal.

e. Consider the effect of the factor at predictor station(s)

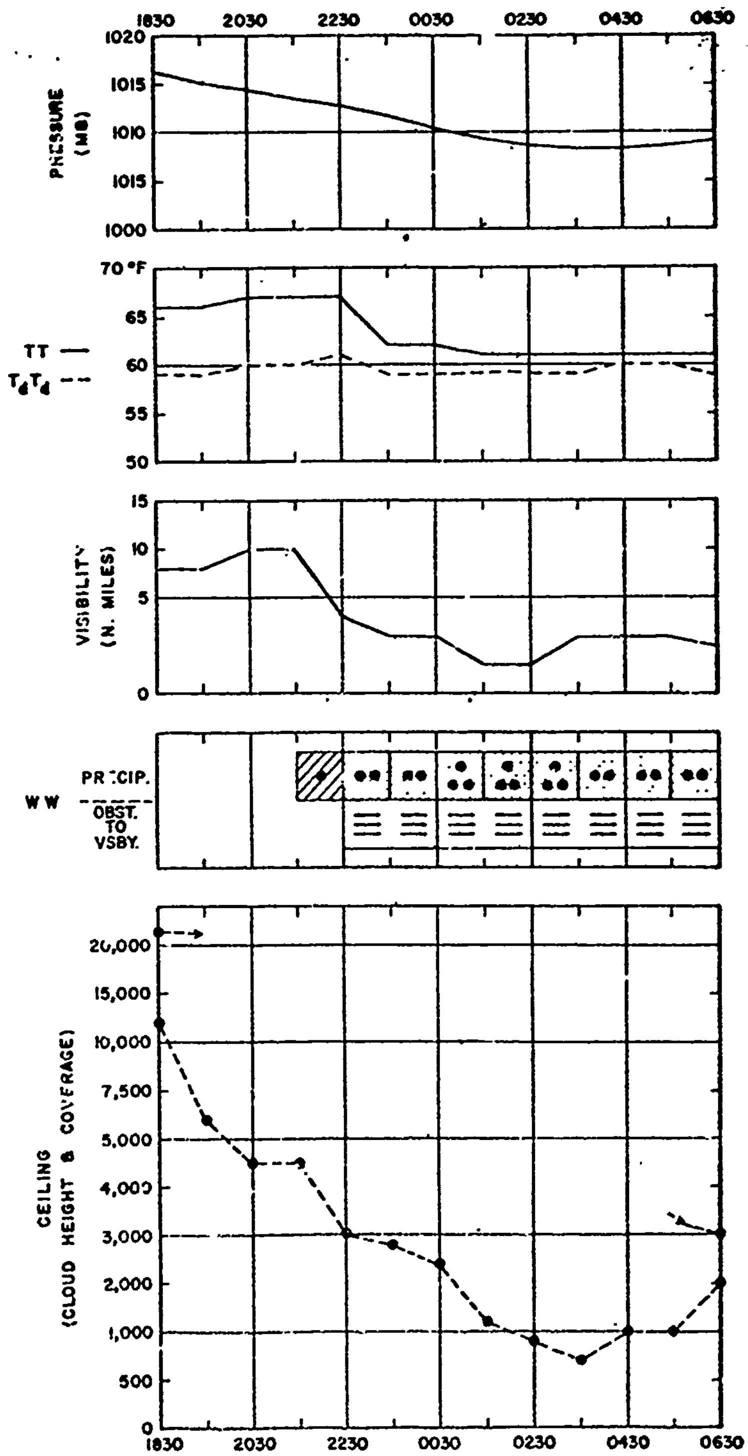


Figure 7. Trend Chart

in forecasting its effect at your terminal.

The main weakness in this procedure is its subjectivity. The forecaster is required to mentally evaluate all of the information available on the hourly sequences both for his own and his predictor station(s). The trend chart is a means to graphically portray the sequences and make extrapolations more objective.

The question thus arises, "How many trend charts do I need?" The answer depends on the synoptic situation. There are times when keeping any graphic record at all is unnecessary; whereas at others the trend for the local terminal may suffice. There should be some blank charts available which may be used to start recording at any time as the need arises. The AWS Form 72, "Station Continuity Chart," is a related type of record, although it is basically an analysis aid.

The trend-chart format shown in Figure 7 is but one suggested way of portraying the weather record. Experimentation and improvisation are encouraged to find the best form for any particular location or problem.

5.4. The "AWS Terminal Forecast Sheet."

In the AWS Operations and Flying Safety Digest, May 1954, a "Terminal Forecast Sheet" was discussed for use as a terminal forecast aid. Since it is quite difficult to retain a mental picture of specific weather data hour by hour, the Terminal Forecast Sheet (see Figure 8) gives the forecaster a continuous visual check of both actual and forecast terminal weather. Each time the observer enters an observation on the WBAN 10, he brings it to the forecaster to check the actual progress of the weather hour by hour with the forecast entries. Thus, it is quite easy to see in symbolic form when and how the forecast is going awry. For example, the check will alert the forecaster when the ceiling is lowering much faster than expected or when the overcast starts breaking a couple of hours early.

Figure 8 is a sample Terminal Forecast Sheet which may be used as a guide. The circled entries show an amended forecast. The forecaster changed his mind after the 0530Z TFAWS was transmitted. It was obvious to him that he had been entirely too optimistic; so the circled entries were made into a revised TFAWS transmitted at 0630E. The use of different colors on the form (for example, red for observations contrary to forecast) may show inconsistencies in an even more striking manner. VFR, IFR, and GCA conditions could also be outlined in different colors.

TERMINAL FORECAST SHEET

Date 15 January 1957 Shift A Forecaster Lt. J. Smith

Time	Forecast 0230-1130E	Forecast 0530-1430E	Forecast 0830-1730E	Observed
0330	20 ⊕ 3 R-F ↗6			23 ⊕5 R-F →6
0430	↓			23 ⊕4 R-F (5000/600) ↗4
0530	INTER 10 ⊕1 RF			23 ⊕4 R-F ↑2
0630		20 ⊕4 R-F →8		6 ⦶15 ⊕3 R-F ↗2
0730		4 ⊕ 1 R-F →5		4 ⊕3 R-F →6
0830	↓	8 ⦷20 ⊕3R ↘12		4 ⊕3 R →8
0930	25 ⦷ 6 RW- ↘25+	25 ⦷ 7 ↘25	4 ⦷20 ⊕3R ↘15	4 ⊕3 R ↘12
1030	35 ⦷ 10 ↘30	25 ⊕6 RW- ↘20	20 ⊕ 7 ↘15	5 ⦶25 ⦷7 ↘20
1130	↓	35 ⦶10 ↘30+	↓	35 ⊕3 RW- ↘20
1230			35 ⦷ 10 ↘20	35 ⦷ 10 ↘26+
1330		25 ⦷9 ↘25+	↓	35 ⦶ 10 ↘25+
1430		↓	35 ⦶10 ↘25+	35 ⦶10 ↘20
1530				35 ⦶10 ↘18
1630				35 ⦶10 ↘18
1730			↓	○ 10 ↘15
1830				○ 18 ↘18

TFAWS groups:

0230 - INTER 105/6 25878 35913

0530 - 25991 35923

0630 - 04516 08726 25828 25933

0830 - 20922 35921 9,'923

Figure 8. AWS Terminal Forecast Sheet.

Chapter VI

"TIME-LINER" CHART AS AN EXTRAPOLATION AID

6.1. Purpose of the Time-Liner.

In the preceding chapters, several methods have been described for "keeping track of the weather." Forms of time-distance charts, isochrone devices, trend charts, etc. have been presented. It is not necessary to utilize all or most of these ideas simultaneously. The device described in this Chapter, however, is designed for use in combination with one or several of the methods described. Time-Liners are especially useful for isochrone analysis and extrapolation therefrom.

Inasmuch as a large majority of incorrect short-range terminal forecasts result from poor timing of weather already occurring "upstream," a device such as described below may improve this timing.

6.2. Construction of the Time-Liner.

The Time-Liner is simply a local-area map which is covered with plexiglass and constructed as follows:

a. Using a large-scale map of the local area (e.g., Sectional Aeronautical Chart), construct a series of concentric circles centered on your station and equally spaced from 10 to 20 miles apart. The distance from the center to the outer circle depends on your location but in most cases about 100-150 miles suffice.

b. Make small numbered or lettered station circles for many stations located at varying distances and directions from your terminal. Stations with a high predictor value, relative to your own terminal, should be selected. This may be determined by experience, local forecast studies, and climatology. Usually, however, the reporting network is not so dense, and most nearby stations can be spotted. In addition to the station circle indicators, significant topographical features such as rivers, mountains, etc. may be indicated on the base diagram. (Aeronautical Charts, of course, include these features.)

c. Cover and bind the map with transparent acetate or plexiglass.

6.3. Plotting and Analysis of the Time-Liner (See Figure 9).

By inspection of his latest surface weather map, sequences, etc., the forecaster determines a section of the diagram and the parameters

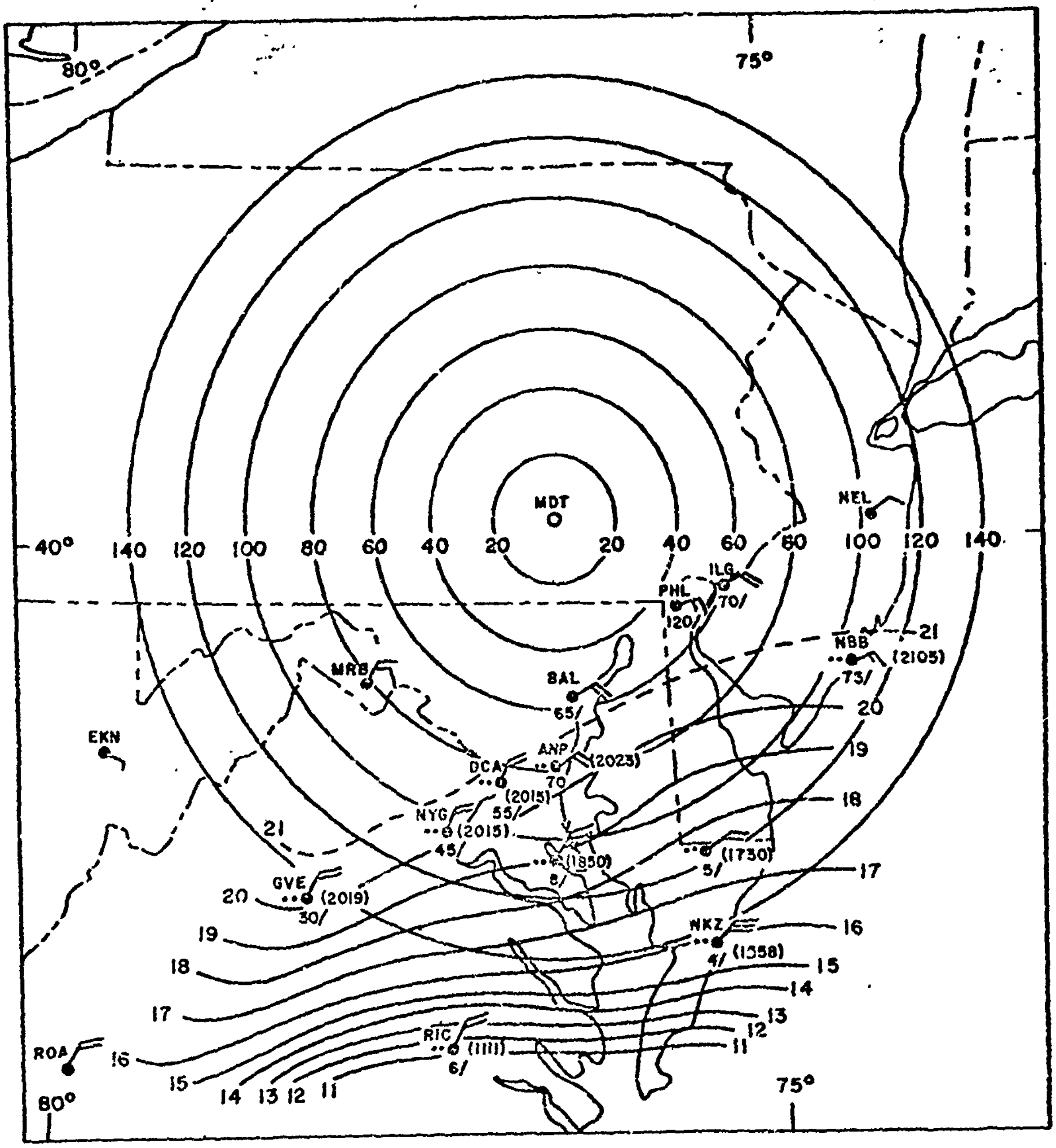


Figure 9. Large-Scale Sample Time-Liner for MDT. (Isochrones show advance of precipitation shield.)

to be plotted. This will usually comprise about one third of the circle in a direction from which the weather is approaching. The observer (or forecaster) then plots the hourly weather SPECIALS for those stations designated by the forecaster, being careful to plot the time of each SPECIAL observation.

Overlay the circular diagram with another piece of plexiglass and construct isochrones of the parameter being forecast (e.g., the time of arrival of the leading or trailing edge of a cloud or precipitation shield). The spacing between isochrones can then be extrapolated to construct "forecast isochrones" for predicting the time of arrival or occurrence of the parameter at your terminal.

The Time-Liner is admittedly a "quick fix" tool; however the fact that it can be plotted and analyzed quickly (say, ten minutes observer time and about five for the forecaster) is a strong point in its favor. If convenient, the distance scale can be constructed to coincide with the scale of the local sectional map used and the isochrones overlaid on the latest analyzed map. This makes a particularly effective briefing aid, since the crew member being briefed can see what he is being told by the forecaster regarding the local area.

The prime use of this device is, of course, for timing or extrapolation purposes. It cannot be emphasized too strongly that accurate timing is a most important facet of short-period terminal forecasting.

Chapter VII

USE OF RADAR IN TERMINAL WEATHER FORECASTING

7.1. Introduction.

Although radar meteorology is still in its infancy, certain aspects are quite well understood and can be used to good advantage in making short-period terminal forecasts.

Radar enables the forecaster to look at the weather picture on a scale mid-way between the strictly local weather observation and the synoptic-chart picture. The forecaster, however, must become thoroughly familiar with the local peculiarities of radar return caused by topography and anomalous propagation situations at his station.

7.2. Radar Scope Interpretation.

Weather patterns are generally so complex that it is customary to use greatly simplified schematic models as guides in analyzing them. This is particularly true of precipitation patterns. With radar, preconceived patterns are not necessary since the radar clearly shows the detailed structures which are present within the general precipitation areas. The PPI (Plan Position Indicator) scope should be used in each situation to determine the character of the echoes which are classified as: 1) isolated, 2) a line of echoes, 3) area echoes, or 4) area echoes with lines superimposed. Scattered echoes may be related to air-mass weather; lines of echoes, to squall lines or cold fronts; certain characteristic curves in echo lines, to frontal waves; widespread relatively homogeneous echo patterns, to warm frontal precipitation under stable conditions (banded structures under less stable conditions).

7.2.1. Identification of Precipitation Areas. One of the most important uses of radar for the terminal forecaster is to help him locate existing precipitation areas in the vicinity of his terminal (up to 250 miles). Once a storm area has been detected, the movement and growth of the system can readily be determined by making successive observations and noting the changes in position and size of the echoes. The movement indicated from successive observations should be extrapolated to determine which storms, if any, are likely to affect the terminal area (assuming that the indicated movement will continue). Obviously, therefore, attention should be focused on potentially critical upstream areas. When it appears that a particular storm area is going to pass over a terminal, the weather conditions which have been reported to be in this storm area should be forecast for the extrapolated time. Of course, allowance must be made for modification by significant local terrain effects and for tendencies of the area to change in size and intensity as indicated by successive radar observations.

7.2.2. Layers and Cells. The general appearance of weather echoes on the PPI and RHI (Range Height Indicator) scopes identifies the type of precipitation in the area. If the weather return on the PPI scope is quite uniform and not distributed in sharply defined cells, it indicates stratiform clouds and precipitation. On the RHI scope this situation is even more pronounced since the layer resembles a horizontal stratus cloud extending out to the limit of detection. When the weather echoes on the PPI are in the form of individual cells, the precipitation is due to convective processes such as showers or thunderstorms. This is also particularly evident on the RHI scope. On both scopes the edges of the echoes are well defined, but in addition on the RHI the echoes are tall and narrow. When convective activity is superimposed on general precipitation, the cells appear as intensifications of the echoes along vertical or nearly vertical lines. Individual echoes, of course, are usually from cells which "feed" on the air around them so that these echoes appear to move with a speed somewhat less than that of the wind. Also, they may tend to grow in a particular direction giving a distorted impression of movement. It must be borne in mind that on the radar scope the life span of an individual cell in a thunderstorm area is of the order of 20 minutes to an hour; however other cells may generate in the vicinity.

7.2.3. Rain or Snow. Since water droplets scatter about 5 times as much energy as corresponding snow crystals, the return from snow tends to be weaker; and the differences of intensity within a snow storm are generally much less than in a rain storm. A typical PPI presentation of snow is a uniform hazy or coarse echo with very diffuse edges. When both snow and rain are present, as is the case when snow falls from a higher cloud but melts to become rain before reaching the ground, the echo differences are particularly striking on the RHI scope. Above the melting level, the returns from snow crystals are weak; at the melting level where the flakes first become coated with water the return is very strong; finally, as they continue to fall as raindrops, their fall velocity increases, and the radar reflectivity decreases. This gives rise to a "bright band" associated with the level of melting as discussed below.

7.2.4. The Melting Level. An estimate of the height of the melting (freezing) level in precipitation areas near the terminal often can be given by the RHI scope. For this, the radar operator should slowly reduce the receiver gain while the antenna is scanning in elevation. An area of stronger return known as the "bright band" (or melting zone) near the suspected altitude of the 0°C isotherm will be visible on the scope. This "bright band" will be slightly below (300-500 feet) the freezing level of the area being scanned. Short range will give the best results on this observation. A well-defined and thin horizontal bright band is indicative of a very stable air. Under extremely unstable conditions, however, the layer represented by the bright band becomes so deep and mixed up that there is little or no effect noticeable on the radar scope.

7.2.5. Observation of Vertical Wind Shear. When the precipitation is showery, the cells may be seen on the RHI scope as separate columns of falling rain or snow. These columns often are distorted from the true vertical by wind shear. To observe this shear effect clearly the antenna must be scanning in the same plane as the wind shear. To do this adjust the azimuth until the greatest distortion from the vertical is observed. Such observations give heights of shear zones and a qualitative estimate of the shear, but considerable experience as well as an accurate knowledge of the fall velocities involved are necessary for more quantitative evaluation.

7.2.6. Stability, Instability, and Turbulence. Radar can be useful in a qualitative evaluation of the degree of turbulence near the terminal in those layers where precipitation is forming or through which it is falling. Horizontally stratified echoes are indicative of smooth air; whereas vertical columns or cellular echoes indicate vertical motions which cause turbulence to aircraft. As previously mentioned, the sharpness of "bright band" is an indication of the stability involved. Sharp wind-shear layers are also an indication of associated turbulence.

It is well-known that the most severe turbulence (as well as heavy icing and damaging hail) is associated with actively developing thunderstorms extending to great heights. During this dangerous growing stage, the top of the radar echo rises rapidly. The growth can best be followed by using the RHI scope and scanning vertically on the azimuth which includes the highest echo. Subsidence of the top of the echo indicates the end of convection and the resulting decrease of turbulence in that particular cell or group of cells.

7.2.7. Aircraft Icing. Radar information may assist in estimating aircraft icing conditions near the terminal. As mentioned in the previous sub-section, the most severe icing is found in tall growing cumulonimbus above the altitude of the melting zone. In such cases, the absence of a bright band near what is known to be the freezing level is an indication of enough convection to cause serious icing within radar echoes above that level. The most severe icing should be forecast near the top of the rapidly growing echo where the liquid water content is a maximum and the temperature may be well below freezing. In the mature stage of a thunderstorm the snow at its top may become heavy enough to give a diffuse or fuzzy echo with a weaker return than the liquid water. This difference of echo appearance is useful for predicting icing probabilities in the various parts of the cloud.

With experience the terminal forecaster should be able to apply the observing ability of weather radar to his advantage in solving forecasting problems for specific types of operations not covered in this Chapter. With the further development of new techniques and equipment, even more extensive use of weather radar will aid the terminal weather forecaster.

For further information and illustrations refer to the following publications:

1. AWS TR 105-97, "The Use of Radar in Weather Forecasting" (especially Section II), November 1952.

2. AWSM 55-6, "Operation and Utilization of the AN/CPS-9 Radar," (especially paragraphs 2600-3830), April 1955.

3. "Radar Scope Interpretations of Wind, Hail, and Heavy Rain Storms Between May 27 and June 8, 1954," G. E. Stout and H. W. Hiser, Bull. Amer. Met. Soc., Vol. 36, No. 10, December 1955.

Chapter VIII

UPPER WINDS

In view of the rapid increase of wind variability with time, a most important step to improve upper-wind forecasts is to systematically chart the 6-hourly winds. Obviously, more accurate short-period upper-wind estimates can be made by using winds only 3-9 hours old (from 6-hourly local wind analyses) than from winds 8-20 hours old (from facsimile contour analyses).

Since upper-wind observing is still far from perfect, the wind reports often contain large errors which become apparent when continuity is applied. Vertical smoothing of the wind profiles should also be a part of this wind criticism. The observer plots the wind profiles for about 8-12 rawins within the local region of interest as well as upstream. The forecaster can then by use of 6-hourly continuity scrutinize the profiles and smooth them to eliminate observational errors as well as non-representative and eddy-type features.

The winds of these smoothed profiles should then be plotted on three small maps corresponding to the level of the maximum wind as well as the levels representing the upper and lower limits of operational interest. When these small regional charts are analyzed for streamlines and isotachs, simple extrapolation based on these charts in conjunction with both horizontal and vertical interpolation will produce any desired spot-wind forecast in the vicinity of the local terminal.

APPENDIX A

CLOUD INFORMATION FROM CODE FORMS IN COMMON AWS USE
(See sub-section 2.3.2)

A1. International Synoptic Code (and Marine Code).

a. Use:

(1) 3-hourly: United States and Canada

(2) 3-, 6-, or 12-hourly: Overseas

b. Symbolic Form (groups with cloud data). -----Nddff VVwwW ----- $N_hC_LhC_MC_H$ ----- ($8N_sCh_sh_s$), where:

(1) N = fraction of sky covered by cloud.

(2) N_h = fraction of sky covered by type of cloud reported for C_L or C_M (not C_H); WMO Code 6. If all clouds are C_L or C_M, then $N = N_h$; N_h may equal but never exceed N.

(3) C_L = predominating (Table 1, Circ. N) type of lower cloud, Sc, St, Cu, Cb; WMO Code 11 (Table 8, Circ. N).

(4) h = height above ground of base of cloud; WMO Code 43 (Table 9, Circ. N): h for C_L is height of lowest visible cloud patch.

(5) C_M = predominant type of middle cloud: Ac, As, Ns; WMO Code 12 (Table 10, Circ. N).

(6) C_H = predominant type of high cloud: Ci, Cc, Cs; WMO Code 13 (Table 11, Circ. N).

(7) N_s = fraction of sky covered by individual cloud layer of type C; WMO Code 60 (Table 1, Circ. N).

(8) C = type of cloud; WMO Code 10 (Table 17, Circ. N).

(9) h_sh_s = height of base of cloud layer whose type is indicated by C; WMO Code 40 (99 numbers, Table 18, Circ. N).

A2. U.S. Airways Report.

a. Use:

(1) Teletype: United States and Canada.

(2) Radio: Far East.

b. Form (contents pertaining to clouds). Ceiling/sky/condition/---/weather/REMARKS: --- cloud data -----.

c. Specifications (see paragraph 1100, 1400, 1510-1541 of Circ. N and AWSM 105-22). Ceiling given as height of lowest layer reported as broken (.6-.9 sky cover), overcast (10/10) or obscured, in nearest 100 feet up to 5000 feet, or nearest 500 feet from 5000-10,000 and to nearest 1000 feet for over 10,000 feet above field. Sky cover is given for each layer; the sum of these is total sky cover. The cloud type for each layer reported under ceiling and sky is stated along ith heights of tops in the "Remarks."

A3. AERO Code.

a. Used in hourly or ½-hourly airways reports: Europe and Asia.

b. Symbolic Form (groups with cloud data). ----Nddff VVwwW--- $8N_sCh_sh_s$ ----, where:

(1) N = fraction of sky covered by cloud (or total sky cover); WMO Code 60 (Table 13, AWSM 105-24).

(2) ww = present weather; WMO Code 92; items 00, 01, 02, and 03 give tendency of state of sky (Table 19, AWSM 105-24).

(3) W = past weather; WMO Code 90 (Table 18, AWSM 105-24) — items 0, 1, and 2 give duration of sky cover.

A4. AIREP Reports.

a. Used in voice reports from transport aircraft to ground stations.

b. Form is in clear, abbreviated text which includes present weather (past 10 minutes) as well as cloud type, amount, and altitudes of bases and tops.

A5. POMAR Code.

a. Used for reports from transport aircraft.

b. Symbolic Form (groups with cloud data). ----- $2C_eh_bh_bh_b$ $1C_eh_th_th_t$ -----, where:

(1) C_e = cloud type in code (see AWSM 105-22, Figure 5).

(2) h_b = altitude of base of cloud C_e in decameters or hundreds of feet.

(3) h_t = altitude of top of cloud C_e.

A6. RECCO Code.

a. Used by regular weather reconnaissance flights (United States and Great Britain).

b. Symbolic Form (groups with cloud data). -----wmWMB

$f_c{}'Q_NQ_EQ_SQ_W$ $1k_nN_1N_2N_3$ ChhHH ----- $6W_sS_sW_cD_w$ ----- $8w_ea_ec_ei_e$

(1) w = present weather: items 0, 1, and 2 give sky cover (see paragraph 3107.1 in AWSM 105-34).

(2) W = past weather (same code as for w).

(3) $f_c{}'$ = flight conditions: gives amount of cloud cover (see paragraph 3108.1 in AWSM 105-34).

(4) Q_N, Q_E, etc. = weather in north, east, etc. quadrants: items 1, 2, 3, 4, and 9 give character of cloud cover from 30 miles to limit of vision.

(5) k_n = number of cloud layers reported (N_1, N_2, N_3, etc).

(6) N_1, N_2, etc. = cloud amount, layer 1, 2, etc., in octants.

(7) C = cloud type, in code (see paragraph 3110.1 in AWSM 105-34).

(8) hh = height of cloud base (above msl) of layer whose form is given by C and coverage by N, in code (see paragraph 3110.21 of AWSM 105-34).

(9) HH = height of cloud top (above msl) of layer C, same code as for hh.

(10) W_c = weather off-course, not predominant in any one quadrant: items 1, 2, 6, 7, 8, and 9 give cloud types or states of sky, in code (see paragraph 3115.4 of AWSM 105-34).

(11) "8" groups, give radar-scope echo distribution (see paragraph 3119 of AWSM 105-34).

APPENDIX B

NOTE ON RELATION OF WIND FIELD TO CLOUD MOTIONS

The relation between the wind field and cloud motions cannot be stated as a simple rule. The individual cloud elements, over short periods of time at least, generally move with the wind where they are. But the large-scale motion of a cloud system as an entity depends on the motion of the associated areas of convergence or vertical motion, so that no universal general relation to the horizontal wind speed is known. Since in middle levels the winds usually move through the troughs and ridges, it can be said that the middle-cloud systems are generally translated somewhat slower than the winds, i.e., from 50 to 90% of the wind speed. Studies have indicated that the middle-cloud systems should move at about 80% of the 500-mb Z-bar flow (see AWSM 105-50/1 and [5]). In general, this relationship is, of course, useful only for those few detachments which make or receive (via facsimile) a Z-bar chart. A short-cut method, however, for estimating the 500-mb Z-bar flow at the point of interest (e.g., edge of an overcast cloud deck) is proposed as follows: Make a 6 latitude-degree grid around the point and oriented parallel to the edge of the cloud (or neph-curve); read off the 500-mb contour heights at these points and compute $\Delta H = \frac{1}{2}(H_3 - H_2 + H_4 - H_1)$, the mean-height difference across the grid normal to the cloud edge (see Figure B1). The speed of the neph-curve or cloud edge can be evaluated with aid of the well-known relation

$$V = 0.8\,\frac{g}{f}\,\frac{\Delta\bar{Z}}{\Delta N} = 0.8K\,\frac{\Delta\bar{Z}\ (\text{ft.})}{\Delta N\ (\text{n. m.})},$$

where .8 is decimal fraction of the space-meaned flow at which the clouds should move, $\frac{\Delta\bar{Z}}{\Delta N}$ (or $\frac{"\Delta H"}{\Delta N}$) is the gradient of the Z-bar flow expressed as 100's of feet per 6 latitude degrees, and K the latitude factor $\frac{21.47}{\sin\phi}$. Choosing $6^\circ \times 60$ n.m. = 360 for ΔN, multiplying by 3 for 3-hour displacement, and dividing by 60 n.m. (for one latitude degree), gives a working formula for the speed of the neph-curve, S_L, in latitude degrees per 3 hours, $S_L = \frac{0.8K}{72}\Delta H$, or $\frac{K\Delta H}{90}$. For greater simplicity we reduce .8 to .72 and get $S_L = \frac{K\Delta H}{100}$. The values of K are (from AWSM 345-1 Rev):

for 60° Latitude: 25
for 50° Latitude: 28
for 40° Latitude: 33
for 30° Latitude: 43

The 6 latitude-degrees must be measured in terms of the latitude of the point of interest, to allow for the changes in chart distance with latitude. However, on the Lambert conformal chart, a single 6 latitude-degree plastic-overlay template constructed for the scale at the standard parallels can be used with sufficient accuracy. The evaluation of S_L from ΔH and ϕ is quickly made on a nomogram, such as illustrated here (Figure B2).

For levels lower than 500-mb, the advection factor .8 would probably increase to about 1.1 or more. These factors have been determined empirically as best-fit averages and there are, of course, deviations in individual cases. The standard deviation at 500 mb is about 18%, and at 700 mb 25%.

The above procedure is recommended only for points where the past history of the cloud movement is not accurately known; otherwise pure extrapolation is probably as good or better, at least for such short periods as 1 to 3 hours.

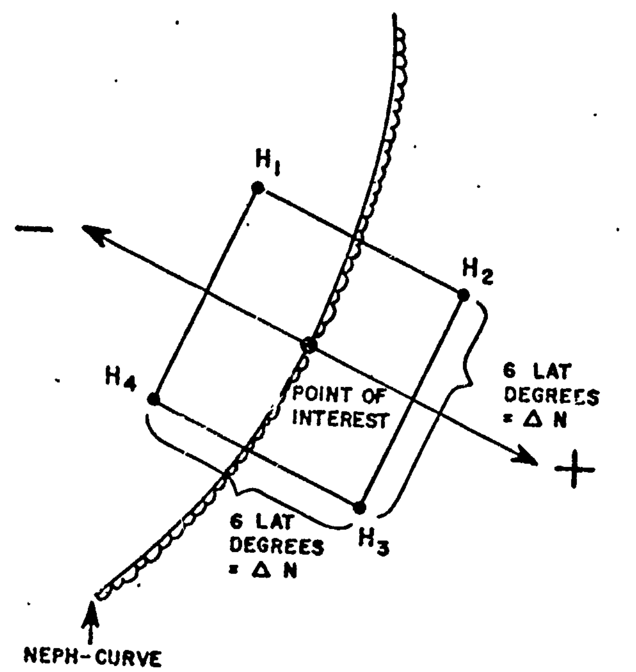


Figure B1. Grid for Computing ΔH.

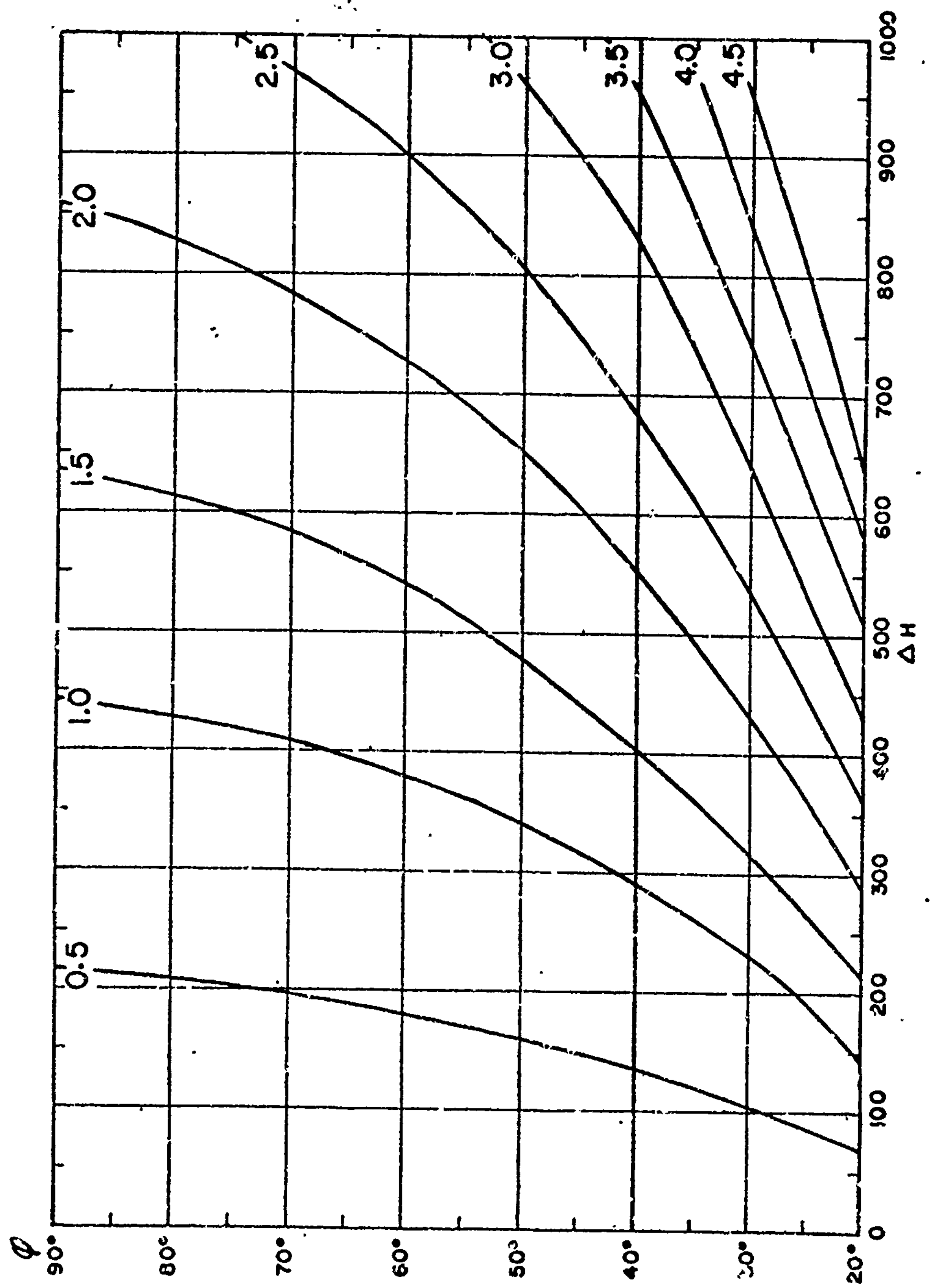


Figure B2. Nomogram for Evaluating S_L from ΔH and Φ. (S_L given in latitude degrees per 3 hours.)

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